CHAPTER 1

INTRODUCTION

1-1. Purpose. This manual provides information, foundation exploration and testing procedures, load test methods, analysis techniques, design criteria and procedures, and construction considerations for the selection, design, and installation of pile foundations. The guidance is based on the present state of technology for pile-soil-structure-foundation interaction behavior. This manual provides design guidance intended specifically for geotechnical and structural engineers and essential information for others interested in understanding construction techniques related to pile behavior during installation. The understanding of pile foundation behavior is actively expanding by ongoing research, prototype, model pile, and pile group testing and development of more refined analytical models. However, this manual is intended to provide examples and procedures of proven technology. This manual will be updated as changes in design and installation procedures are developed.

1-2. Applicability. This manual is applicable to all USACE commands having civil works responsibilities, especially those geotechnical and structural engineers charged with the responsibility for design and installation of safe and economical pile foundations.

1-3. References, Bibliographical and Related Material.

a. US Army Corps of Engineers Directives are listed in Appendix A.

b. Bibliographical and related material is listed in Appendix B, numbered, and cited in the text by the corresponding item number. These selections pertain to pile foundations for general knowledge and contain further expanded and related material.

c. A series of computer programs are available to assist in analyzing and designing pile foundations in accordance with the engineering manual. This series of programs includes:

(1) Pile Group Analysis (CPGA) which is a stiffness analysis of three-dimensional pile groups assuming linear elastic pile-soil interaction and a rigid pile cap.

(2) Pile Group Graphics (CPGG) which displays geometry and the results of CPGA.

(3) Pile Group Stiffness (CPGS) which determines the pile head stiffness coefficients for a single vertical pile, and computes the displacements, internal forces and moments, and axial and lateral soil pressures acting on a pile due to specified loads or displacements at the pile head.

(4) Pile Group Dynamics (CPGD) which extends the capability of CPGA to account for dynamic loading.

(5) Pile Group Concrete (CPGC) which develops the interaction diagrams and data required to investigate the structural capacity of prestressed concrete piles.

(6) Pile Group Interference (CPGI) which investigates the pile layout for geometric interference due to the intersection of piles during driving.

(7) Pile Group Optimization (CPGO) which solves for the optimal arrangement of a pile group using data and analysis results from GPGA.

(8) Pile Group Base (CPGB) which analyzes a rigid base slab or pile cap for pile loads determined by CPGA.

(9) Pile Group Flexible (CPGF) which extends the capability of CPGA to account for the flexibility of the base slab or pile cap.

(10) Pile Group Probabilistic (CPGP) which extends the capability of CPGI to account for probabilistic variations in pile driving tolerances, tolerable manufacturing imperfections, pile flexibility, and subsurface obstructions.

The first five programs are available for use, and the remaining programs are under development. Other programs will be added to the series as needs are identified. Currently available programs are fully described in Items 5, 6, 15, and 16, respectively. The theoretical background for these computer programs and this Engineer Manual will be provided in "Theoretical Manual for the Design of Pile Foundations." The Theoretical Manual is currently in preparation and is intended to be a companion volume that provides a detailed discussion of the techniques used for the design/analysis of pile foundations as presented in this manual and used in the available computer programs listed on pp 1-1 and 1-2. It will present the theoretical development of these engineering procedures, how they were implemented in computer programs, and discussions on the limitations of each method.

d. A case history of pile driving at Lock and Dam No. 1, Red River Waterway, is presented in Appendix C.

e. Examples of pile capacity computations are presented in Appendix D.

1-4. Definitions.

a. Pile Foundation. In this manual, a pile foundation will be broadly described as one in which the following is true of the piles:

(1) Piles are driven, not drilled.

(2) Standard commercial, not special patent, piles are used.

(3) Usually steel or prestressed concrete piles are used for major hydraulic structures, but reinforced concrete or timber piles should also be considered.

b. Pile Industry Terms. Since many of the terms used in the piling (material, equipment, and driving) industry seem to be unique to this industry, it is suggested that reference be made to the Deep Foundations Institute (Item 32). These definitions are adhered to in this manual.

c. Units of Measurement. The English system of measurement units have been used exclusively throughout this manual.

d. Notations and Symbols. There is no unified set of symbols and nomenclature for the analysis and design of pile groups. Pile technology has evolved over the last three decades and different symbols appear throughout the engineering literature for describing the various geotechnical and structural aspects of single pile and pile group behavior. This has presented a major problem in writing this EM. The following approach was adopted:

(1) It was not practical to develop a unified system of symbols and nomenclature.

(2) Critical symbols which have attained recognition as defacto standards throughout the profession (such as p-y and t-z curves) and within the Corps of Engineers (such as X, Y, and Z for the global coordinate axes and 1, 2, and 3 for the local pile coordinate axes) will be identified. Some symbols may therefore have dual meanings (such as x, y, and z for local coordinates or as local pile displacements).

e. Style of Presentation. The EM was written in a manner to assist readers struggling with the difficulties of the symbols and nomenclature and the inherent technical complexity of pile behavior. Footnotes are used when a symbol which has a dual meaning is introduced. This minimizes potential problems by explaining the meaning for that particular application and gives the key references for a detailed explanation.

f. Alternative Foundation Designs. The first consideration in the design of a structural foundation should be the subsurface investigation. The data from such investigations should be evaluated to determine whether or not the use of a pile foundation is necessary. If such studies, together with studies of the soil properties, reveal that detrimental settlement can be avoided by more economical methods or that a pile foundation will not prevent detrimental settlement, then piles should not be used. A preliminary selection of the pile type may usually be made from a study of the foundation investigations. However, the nature of the structure, type of applied loads, and technical and economic feasibility must be considered in the determination of pile type, length, spacing, batters, etc.

(1) If the boring data reveal that timber piles would not be damaged by driving, such type may be considered. Steel bearing piles may be desirable if boulders or hard strata are present in the area of pile driving. In deposits of sands, silts, and clays that are relatively free of boulders, consideration should be given to the use of concrete piles. However, considerable difficulty and problems often occur in driving displacement piles in granular soils such as sands, silty-sands, and sandy silts.

(2) The load-bearing stratum or strata can be selected from a study of the soil profiles and characteristics of the soil. By estimating the required length of penetration into the load-bearing material, the lengths of piles may be reasonably approximated. In designing friction pile foundations, advantage should be taken of increased capacity with greater depths by favoring fewer piles with greater lengths.

(3) In cases where piles are to be driven into or underlain by cohesive soils, the foundation should be investigated to determine the type and length of piles and the size and shape of the structural foundation which will result in a minimum of ultimate settlement. In wide foundations, long, heavily

loaded, widely spaced piles will result in less settlement than short, lightly loaded, closely spaced piles.